# Temperature performance of AlGaN/GaN MOS-HEMTs on Si substrates using $Gd_2O_3$ as gate dielectric

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GaN based high electron mobility transistors have draw great attention due to its potential in high temperature, high power and high frequency applications [1, 2]. However, significant gate leakage current is still one of the issues which need to be solved to improve the performance and reliability of the devices [3]. Several research groups have contributed to solve this problem by using metal–oxide–semiconductor HEMTs (MOSHEMTs), with a thin dielectric layer, such as $SiO_2$ [4], $Al_2O_3$ [5], $HfO_2$ [6] and $Gd_2O_3$ [7] between the gate and the barrier layer on AlGaN/GaN heterostructures. $Gd_2O_3$ has shown low interfacial density of states($D_{it}$) with GaN and a high dielectric constant and low electrical leakage currents [8], thus is considered as a promising candidate for the gate dielectrics on GaN. MOS-HEMTs using $Gd_2O_3$ grown by electron-beam heating [7] or molecular beam epitaxy (MBE) [8] on GaN or AlGan/GaN structure have been investigated, but further research is still needed in $Gd_2O_3$ based AlGaN/GaN MOSHEMTs.

The high-temperature operation of AlGaN/GaN HEMTs on Si has been evaluated previously by several groups [9, 10]. However, there has been very little work on the thermal stability of insulated-gate AlGaN/GaN structures on Si substrates for high-temperature applications.

In this work, thermal stability of $Gd_2O_3$ based AlGaN/GaN MOSHEMTs on Si substrates were studied and compared with standard AlGaN/GaN HEMTs.

A thin layer of $Gd_2O_3$ with (4.2 ± 0.3 nm) thickness and 2.1 nm root mean square (RMS), was deposited using high pressure sputtering technique [11] as the gate dielectric of AlGaN/GaN based HEMTs. IV DC and pulse characterization was carried out at room temperature (RT). The MOSHEMTs transistors showed an OFF-state ($V_{GS}$=−8 V) drain-source leakage current density at $V_{DS}$ =15 V of $1.1\times10^{-4}$ A/cm$^2$, which is about four orders of magnitude lower than in the conventional, reference HEMTs. However, no significant differences were observed in the saturation drain-source current density ($I_{DSS}$) (0.63±0.3 A/mm) and peak transconductance ($g_{m,max}$) (135±5 mS/mm) for both kinds of devices. In addition, both the

MOSHEMTs and HEMTs showed similar gate lag ratios, which could be attributed to trapped charges in the unpassivated area between gate and drain.

The same electrical measurement procedure was conducted on the devices during and after a thermal cycle from RT to 425°C with a 100°C step. The results showed that the off-state drain source leakage current was quite stable (5 nA/mm) with increasing temperature in the MOSHEMTs, but it increased with a rate of one magnitude per 100°C (from 80 nA/mm at RT to 0.2 mA/mm at 425°C) in conventional HEMTs as shown in Fig. 1. Therefore, MOSHEMTs show better thermal stability than conventional HEMTs.

As expected, $I_{DSS}$ and $g_m$ decreased with increasing temperature for both MOSHEMTs and HEMTs, although the decrease in MOSHEMTs is 15% smaller than that of HEMTs. The threshold voltage showed a positive shift at high temperature in MOSHEMTs, and stays stable after the thermal cycle at RT (-4.4 V), which suggested that the thermal treatment contributed to improve the interface between the $Gd_2O_3$ layer and the AlGaN/GaN heterostructure, while maintaining the low leakage current.

In conclusion, GaN-based MOSHEMTs with $Gd_2O_3$ are more suitable devices for high temperature applications than the conventional HEMTs, due to smaller and more stable gate leakage current up to ~400°C, and the lower decrease in $I_{DSS}$ and $g_{m,max}$ during the device heating.

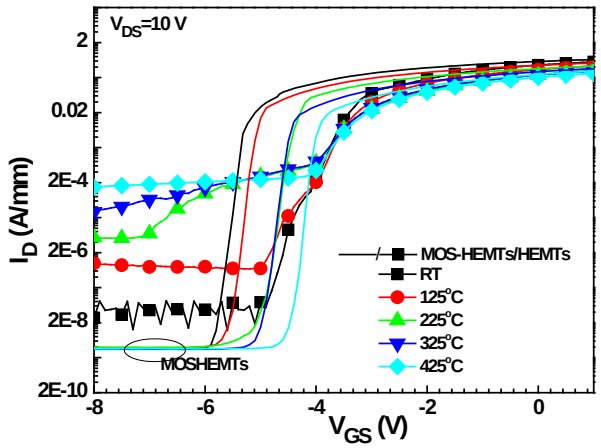


***Figure 1:*** *$I_D$-$V_{GS}$-T of the MOSHEMT (solid lines) and HEMT (symbol-lines) devices at $V_{DS}$ = 10 V.*

This work was supported by RUE (CSD2009-00046), CAVE (TEC2012-38247) and TEC2010-19051 projects, from MINECO (Ministerio de Economía y Competitividad) in Spain.

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